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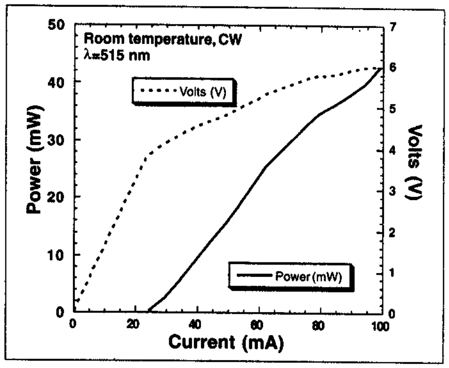
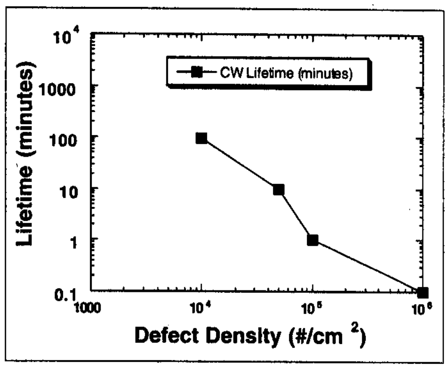
The remaining challenge for II-VI light emitting devices has been , and continues to be, the degradation and eventual device failure due to crystalline defects. Defects originating at the GaAs/II-VI interface propagate upwards during growth and intersect the quantum well. During device operation dark lines nucleate at these intersections and grow along the quantum well plane. This reduces the total area available for optical gain and causing the device to dim. This type of failure was observed in early GaAs based laser diodes. As the number of defects in the II-VI material has been reduced the device lifetimes have increased dramatically as illustrated in Fig. 4. By reducing the number of defects to the point where an individual laser contains no defects, a density of about 1 X 10^3 cm^2, it is expected that the lifetimes will no longer be limited by this failure mechanism.

Blue-green laser diodes have matured rapidly over the past 4 years since they were first demonstrated. CW lifetimes have increased, over the past two years, from seconds to more than three hours.



▼ *Figure 3. Typical L-I-V characteristic of a blue-green laser diode operting at 515 nm. The power output, given in mW/facet is in excess of 40 mW which is more than twice the power needed for optical recording systems.*



▼ *Figure 4. Lifetimes of blue-green laser diodes have made dramatic increases as the defect density is reduced. As the density approaches 1 X 10^3 cm^{-2} device performance is expected to improve even more - a result of each device statistically containing less than one defect.*

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HOT TOPIC

Metastable Atom Lithography: A New Technique for Creating Nanostructures

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Think small: imagine the width of a human hair (100 μm) magnified to the size of a football field. At this scale, the size of a modern computer chip would be over 18 km (10 miles) wide, but the circuit features would be only about 30 cm (one foot) across. The remarkable level of detail in microelectronic circuits is the result of several decades of breakneck progress in miniaturization, fueled primarily by technical improvements in photolithography, the process by which photons are used in conjunction with chemical processing to pattern surfaces.

There is a problem on the horizon, however. Progress in optical photolithography will soon run into trouble, and this time it will be serious. A basic principle of physics in both wave optics and quantum mechanics, the uncertainty principle, imposes severe restrictions on what is possible in the microworld, and our most advanced industrial production lines are beginning to approach these restrictions. As the size of circuit features shrinks below the wavelength of light, everything begins to blur—not due to practical defects in the technology, but because nature is putting on the brakes in a very fundamental way. New methods of miniaturization will be required in order to maintain progress.

Because the problem is so fundamental, a large number of basic research scientists have begun to tackle it to search for answers and new methods. One class of approaches involves doing lithography with matter particles instead of photons. Unlike the massless photons, matter particles have quantum wavelengths that are so small that by present standards their fuzziness is not a problem. Matter-particle lithography is a well-develpattern we created is less than 100 nm, but this appears to be limited by the roughness of the grid itself rather than by any inherent process in the metastable atom lithography. Calculations by one of Prentiss' new graduate students, Arthur Chu, indicate that replacing the grid with the appropriate configuration of laser fields will allow us to reduce the feature size to 10-20 nm. Work towards this goal is presently underway in the laboratory.

It is worth mentioning that this experiment has a sociological aspect as well as a physical one. The work described here illustrates the type of progress that can be made when scientists engaged in basic research in various disciplines combine their thoughts, experience, hardware, and personnel to collaborate on a frontier research problem. That paradigm of collaborative activity for the advancement of scientific goals offers an appealing alternative to the inter-group competition which otherwise arises naturally in an environment of restricted science funding. Our particular collaboration has been made possible through the National Science Foundation's effort to foster such a cooperative venture by establishing the Consortium for Light Force Dynamics, and by the scientific exchange program of the Alexander von Humboldt Foundation.

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PRESIDENT'S COLUMN

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provide services directed toward the "practicing engineers". I am soliciting suggestions and volunteers to help us grow this area of activity with the hope of perhaps forming an applications oriented conference and/or journal in Electro-Optics.

In concert with the above activity, the LEOS long range planning committee (LRPC) is examining the membership implications of all the "rightsizing" changes and globalization in our community on membership. The LRPC is the LEOS body which is responsible for developing the five year plan defining the future directions for the society. It is clear that over the past several years, there have been significant shifts in membership. Many from our community have followed jobs that have moved them into the more applied areas of Electro-Optics or out of Electro-Optics altogether. The non-U.S. component of our membership has grown significantly, now accounting for approximately 45% of the LEOS membership. LRPC has been studying these movements and will be recommending at the next Board of Governors meeting changes in the LEOS Vice Presidential Structure that will better position the society to react to our changing environment. Specifically, the recommendation will be put forth which will better focus our efforts on globalization and the changing employment picture. This recommendation proposes that three new Vice Presidential positions be created tentatively titled Vice President for Membership and Regional Activities. There will be one appointed each from Europe/Middle East/Africa, Asia and Pacific and the Americas. They will be responsible for the LEOS activities in their regions in the following areas: *Membership, Chapters, Fellow Nominations,* aid to *Emerging Countries, and International Activities.* Each of these regional V.P's. would have the freedom to propose their own committee structure to oversee and execute the above activities. The current thinking is that the different regions may have different needs. Each regional Vice President will be strongly encouraged by me to take a high degree of interest in the local chapters in their regions with the goal of trying to expand and strengthen them. LRPC will suggest that annual chapters meeting in each region be held in concert with a major regional LEOS meeting, such as CLEO/Europe, CLEO/Pacific RIM etc. This will provide a forum for communications among regional chapters and an opportunity for the Board of Governors Members to interact directly with the chapters. I further plan to encourage the BOG members to actively participate in local chapter activities so that these chapters are effectively represented at the BOG meetings.

As is apparent, LEOS wants to respond to its needs of the Electro-Optics community. We are increasing our efforts in this arena and are looking to you for assistance. Please feel free to call or E-Mail Ed Labuda at 908-562-3891 - e.labuda@ ieee.org or myself at 202-767-3171 (FAX: 202-767-9300) with your suggestions on how to improve services, attract members or serve more of our community. We need active participation if we are going to be successful in serving you.

Reviewers Needed

The number of papers LEOS and other organizations publish continues to grow. At the same time, some of you may have noticed that changes in the workplace are demanding more and more of our time! It's no surprise that many reviewers are becoming increasingly reluctant to review papers, or at least to turn them around quickly. The only solution is to provide our Editors and Associate Editors with names of additional candidate reviewers for help. If you are willing to review papers in JQE, PTL, JSTQE, and/or JLT, please let us know. We would like your name, affiliation, telephone and fax numbers, e-mail and regular mail addresses, and technical areas (and even specific journals) where you would like to receive papers for review. Please send this information by fax or e-mail to Fran Jetko (f.jetko@ieee.org) at our Editorial Office. Thanks very much.

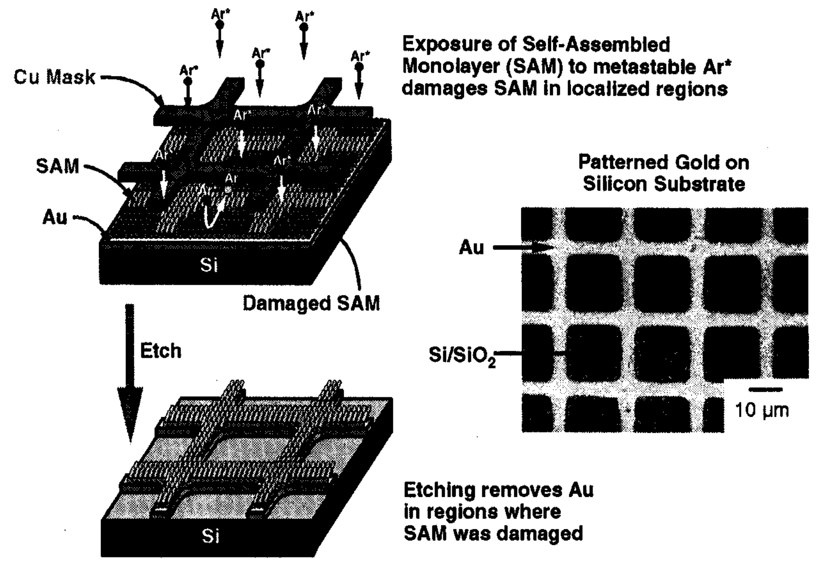
oped technology, but virtually all of this work has depended on using the kinetic energy of high-velocity charged particles, either electrons or ions. Now, in a collaboration which combines expertise from several different research groups at NIST with that from several different academic departments at Harvard, we have demonstrated a new type of matter-particle lithography which uses slow neutral atoms of inert gas. We have used the method to produce micropatterns of gold on silicon [1].

The gases we use are helium and argon, materials which are ordinarily as benign as one can imagine. The key, however, is to first modify the internal quantum states of the atoms so they are left in an electronically excited metastable state. The energy required to prepare this state is stored in the atom. If such an atom is prevented from coming in contact with another atom, it will stay in the metastable state for a long time—more than enough time to manipulate it onto a surface in a controlled way inside a vacuum chamber. When the metastable atom hits the surface, it is jarred out of the metastable state and relaxes back down to the normal ground state, releasing its stored energy in the process. The metastable atoms thus act as tiny bombs, carrying their energy to a particular location and then releasing it locally.

The idea of using metastable atoms to pattern lithographic resists first occurred to Jabez McClelland several years ago [2], and shortly thereafter he and John Gillaspy set out to test the idea in a laboratory at NIST where Gillaspy had been experimenting with metastable atoms for other reasons. Basic research on the frontier of science often requires wandering up a few alleys before finding the right path, and this work was no exception: our first test was a dismal failure—conventional lithographic resists were left unscathed by the metastable atom bombardment.

The solution to the problem came independently from an unexpected source. As part of an NSF-supported collaboration involving groups from Harvard, NIST and Bell Labs, Mara Prentiss of Harvard's Physics department and George Whitesides of the Chemistry department had been working on using alkali atoms to expose an ultra-thin resist composed of a self-assembled monolayer (SAM) polymer. They were having problems because a large dose of alkali atoms was needed to damage the SAM. While Whitesides was discussing these experiments with

MICROLITHOGRAPHY USING METASTABLE ATOMS



▼ *Figure 1. The MetaSAM lithography technique, as implemented with a stencil mask. Also shown is an electron micrograph of the grid of gold lines produced with the method. (Illustrations courtesy Bob Dragoset and Andras Vladar, NIST).*

Bill Phillips' group at NIST, where Steve Rolston was experimenting with the optical manipulation of metastable atoms, the idea was developed to use metastable atoms to expose a SAM resist. Prentiss and Whitesides soon joined forces with Gillaspy, McClelland, Phillips and Rolston to determine whether the combination of metastable atoms and SAMs would meet the lithographic goals we were all pursuing.

If we could show that metastable atoms could indeed modify the SAM resists, then there would be an immediate opportunity to use laser-assisted control of the atomic beam to make nanoscale features. Phillips and Prentiss had invented and then helped develop many of the laser-atom manipulation techniques [4] that McClelland and others had been using in pioneering nanofabrication applications during the past few years [5], so the "metastable-atom on SAM" (MetaSAM) collaboration had all the expertise, both in physics and chemistry, needed to carry out the project.

The team of experts still needed someone who could focus their activity on the daily laboratory work necessary to make the ideas a reality. This came in the form of three young scientists, Andreas Bard, a postdoc who had just arrived from Germany and begun work in Gillaspy's metastable atom and laser laboratory, Karl Berggren, one of Prentiss' graduate students at Harvard, and Jim Wilbur, a postdoc from Whitesides group. With this assembly, the MetaSAM collaboration was launched into action. Initially, we didn't know for sure whether the idea would work, but within a month we had the long-awaited result: metastable helium atoms had passed through a triangular aperture and burned a correspondingly shaped spot on a self-assembled monolayer. MetaSAM lithography, as we sometimes call the process, had become a reality.

We began the work with helium because its metastable states have the most stored internal energy of any neutral atom on the periodic table, and this should maximize our chances of success. We quickly showed that the process also works for metastable argon, however, which has only half as much energy stored in the metastable state. We then went on to do some studies to rule out the possibility that the triangle was formed by something else in the beam other than metastable atoms (like UV photons or electrons, for example). These control experiments were facilitated by our ability to manipulate the atom's state optically: a laser beam was used to remove the atom from the metastable state, effectively disarming the "bomb" before it hit the SAM surface. Finally, we used a microgrid to cut a pattern in the atomic beam which we transferred onto the surface, as illustrated in figure 1. The edge roughness of the grid